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New York Balance Demonstration
#4-14501

Warning:

- **Not a toy; use only in a laboratory or educational setting.**
- **May contain lead - do not ingest**
- **California Proposition 65 Warning: This product may contain chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.**

Introduction

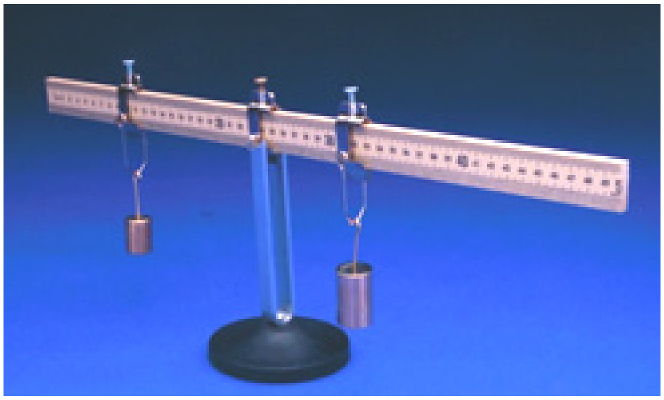
The New York Balance is a visual demonstration of some basic principle in physics; torque, levers, center of gravity and kinetic energy.

To assemble, attached the "U" shaped upright support to the based using the hardware provided. Please be sure to tighten the screw that holds the center support to the base. The knife edge clamp without the hanger wire is to be used as the fulcrum or fixed point from which the 50 centimeter ruler will pivot.

First, set up the balance with the fulcrum clamp set on the 25cm mark; this is the center of the ruler. The clamp should be mounted with the screw on the bottom. This will place the balance arms above the horizontal center of the rule.

Next, place the two other knife edge clamps with hanger wires on each end of the ruler with the screw on top and the hanger wire hanging below the ruler. Line the balance arm of the left clamp with the 1cm mark. Line the right clamp with the 49cm mark. If the ruler does not balance, move the fulcrum (center) clamp toward the lower side slightly until the ruler does balance. Now add the 100 gram weight to the left hanger and the 50 gram weight to the right hanger. Of course, the left side of the balance will go down until the weight rests on the table. Move the left hanger with the 100 gram weight in toward the fulcrum until the ruler again balances. You should find the left clamp setting at about 11cm mark.

Now, let's analyze what has happened. We have a 50 gram weight that is balancing a 100 gram weight. But, in order for the ruler to be balanced, the forces must be equal on both sides. That means that there is another factor in this equation. This factor is the distance from the fulcrum at which the forces are applied.



The size of a turning force is called moment of force or torque and it is the distance from the fulcrum times the force applied. In this case, the 100 gram weight is 14cm from the fulcrum (14cm x 100 grams = 1400 grams of torque). The 50 gram weight is 24cm from the fulcrum (24cm x 50 grams = 1200 grams of torque). 1200??? Wait a minute, 1200 is not equal to 1400. So, why is the ruler balanced? Here is a clue; think about the weight of the clamp? When each clamp was at the end of the ruler, their weight was negligible because they balanced each other. But now that they are set at different points from the fulcrum, each clamp applies a different amount of torque. Each clamp weighs approximately 19 grams. The force of each clamp needs to be added to that of the hanging weight. So, on the left side of the balance we have 100 grams + 19 grams for the weight hanger, set 24cm from the fulcrum. On the right side of the balance, we have 50 grams + 19 grams for the weight hanger, set 24cm from the fulcrum.

Recalculating:
Left side of the balance, 119 grams x 14cm = 1666 grams of torque.

Right side of the balance, 69 grams x 24cm = 1656 grams of torque.

The difference is less than 1% of error (very good). Whenever you make the transition from paper calculations to real world application, you can expect some error due to slight variations in material, human error or other outside forces that were not taken into consideration.
So, for all practical purposes, the ruler is now balanced.

When a smaller force (50 grams), is moving a larger force (100 grams), there is a mechanical advantage. However, there is a price for the mechanical advantage. In order to gain the mechanical advantage, you have to give up something. In this case, you give up distance. If you take another look at your set-up and rock the arm up and down, you will find that the clamp on the right side is moving about twice the distance as the clamp on the left side. When the left side goes down one inch, the right side goes up two inches, approximately. In actuality, to figure the mechanical advantage, you would take the smaller force, 69 grams, and divide it by the larger force, 119 grams, to give you a mechanical advantage of 1.72. This means that if the left side moves down one inch, the right side will travel 1 inch x 1.72 or 1.72 inches. The distance traveled is directly related to the mechanical advantage. This type of lever is known as a first class lever.

Now, for a different type of set-up; put the left clamp on 1cm and the right clamp on 49cm. Adjust the weight on the heavier side of the ruler until it is balanced. Now, move the fulcrum toward the left side. The screw in the center knife edge clamp (fulcrum) will have to be loosened so the ruler can move freely. However, try to keep some tension on the screw so the ruler will stay in place. When the ruler is balanced, tighten the screw. You should now have a weight on each end of the ruler but the fulcrum should be at approximately 19.5cm. This will place 119 grams on the left side, 18.5cm away from the fulcrum. On the right side, you will have 69 grams of weight at 29.5cm from the fulcrum.

Using our equation:
119 grams x 18.5cm = 2201 grams of torque.

69 grams x 29.5 cm = 2035 grams of torque.

Notice that the formula is not balanced but the ruler is balanced. Welcome to the real world of physics! Quite often theoretical equations are hard to duplicate due to factors like friction, static, air currents, etc. But you can be sure that the force on one side of the beam is equal to the force on the other side. Can you diagnose the problem? Did you notice that more of the ruler is extending from the right side versus the left? That's right; the extra length of the ruler is adding torque to the set-up. You have 11cm more of the ruler on the right side of the fulcrum. The weight of the ruler varies from stick to stick, but for calculation purposes, each centimeter of ruler is approximately 0.6 grams. So you actually have 11 x 0.6 or 6.6 grams of weight that must be added to the calculation. This should be simple enough but things are not always what they seem. You cannot just add 6.6 grams more weight to the 69 grams already hanging on the ruler. Why; because of the position of the weight. If we have 19.5cm of ruler on the left, then 19.5cm of ruler on the right would balance this or cancel the weight of the ruler. However, to the right of that, we have 1cm of ruler exerting a torque of 12.3 grams (0.6 x 21.5). We can continue until we reach the end of the ruler. However, you can also take the equation 0.6 x (20.5cm +21.5 + 22.5cm + 23.5cm….) all the way to the end of the ruler, which would be 30.5cm from the fulcrum. To make things easier for you, this number is 168.3 grams (280.5 x 0.6). Now, if you add the extra torque, 168 grams, to the already established torque of 2035, you get 2203 grams of torque on the right side and 2201 on the left side. The difference is less than ½ of 1% error! By compensating for the variables, even a simple demonstration tool can be very accurate.